EXAMINING THE EFFECTIVENESS OF ANKLE PROPHYLAXES ON REDUCING LATERAL ANKLE SPRAIN MECHANICS FOLLOWING EXERCISE

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Abstract

Lateral ankle sprains are the most common injury among collegiate athletes. Because of this, prophylactic ankle devices like taping and bracing are widely used to reduce the risk of sustaining this injury. Though there is some literature that shows how effective different taping and bracing methods are at restricting ankle inversion following exercise, most measurements taken are limited to patient-motivated ones such as a Y-balance test, non-weight bearing assessments, and measurements that are taken immediately after the device was applied. Since athletes are prone to injuries during exercise, measuring the effectiveness of ankle bracing and taping should be done after an exercise protocol via a dynamic walkway. The purpose of this study was to evaluate changes in time to maximal inversion, velocity of inversion, and maximal inversion following exercise in various ankle prophylactic conditions, as well as patient-perceived comfort of the devices.

The restrictiveness of two taping methods and one ankle brace were measured, as well as participant-perceived comfort rating. A total of 15, physically active subjects were asked to report for four days of testing: one day for each condition (white cloth tape, self-adherent tape, lace-up ankle brace, and control). The subject was then asked to complete an exercise protocol to mimic sports participation. Following the exercise protocol, the subject was fitted with a wireless electrogoniometer to the tested ankle, and the ankle mechanics assessment on the perturbation walkway was done. Finally, subjects assessed their comfort rating of the prophylactic device on a VAS scale. A Repeated Measures Analysis of Variance was calculated for each of the four dependent variables, and the level of statistical significance was set to $\alpha<0.05$. A Hedges g effect size was also calculated for each dependent variable relationship.

There was a significant decrease in range of motion between the prophylactic devices $F_{(3,42)}=6.769$, $p=0.001$, $\eta^2=0.668$, $1-\beta=0.950$, with the brace resulting in 14.2 ± 0.7 degrees, control 17.8 ± 0.7 degrees, self-adherent tape was 16.4 ± 0.8 degrees, and white tape was 16.4 ± 0.9 degrees. Follow-up analysis showed there was not a statistically significant effect for prophylactic conditions for time to max inversion, with the brace having 152.5 ± 10.6 ms, the control having 125.9 ± 5.7 ms, self-adherent tape 126.7 ± 6.7 ms, and white tape at 143.1 ± 10.3 ms. There was a statistically significant effect for prophylactic condition for the dependent variable velocity, $F_{(2.122,29.714)}=14.706$, $p<0.001$, $\eta^2=0.942$, $1-\beta=1.00$, with the brace having 93.3 ± 7.3 deg/s, control 148.9 ± 7.1 deg/s, self-adherent tape 137.6 ± 9.3 deg/s, and the white tape 124.5 ± 8.8 deg/s. Large effect sizes were noted between some variables, which may show a clinical difference, albeit no statistical significance. A large effect size showed that the brace was perceived as more comfortable when compared to the self-adherent tape (g = 2.1) and white cloth tape (g = 2.2).

As shown by the statistical analysis and data, the lace-up ankle brace may be the most effective prophylaxis at reducing overall ankle range of motion and is also perceived as more comfortable.

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Introduction

Lateral ankle sprains are the most commonly reported injury diagnosis among US collegiate student athletes, with 13.6 incidences in females and 6.94 incidences in males per 1,000 exposures.[1-3] From 1977 to 2005, the incidence of lateral ankle sprains per 1000 person-exposures ranged from 0.90 in field hockey athletes, to 40.06, in netball athletes.[4] In the National Football League (NFL), 53.2% of players had a history of ankle sprains. Injuries to the anterior talofibular ligament comprised 12.7% of all ankle sprains reported between 2009 and 2015 at the NFL Combine. A total of 53 lateral ankle sprains were reported during the regular NFL season over a 15-year time period.[5,6] These ankle injuries can result in significant time lost from their respective sport. The average time lost by an NFL player who sustains an ankle sprain was 6.5 days.[5]

The most common prophylactic support used to prevent recurrent ankle injuries is white cloth tape with a foam underwrap.[7,8] Athletic trainers are initially taught to tape an ankle using these materials. It has been reported that nearly half of athletic trainers encourage taping, while 24.1% of them require it for their athletes.[9] The goal for ankle taping is to try to limit injurious range of motion, while still allowing for the range of motion necessary to participate in sport, thus reducing the potential for a lateral ankle sprain.[10] Alternatives to traditional white cloth taping techniques are also used for prophylactic purposes. One method frequently used is self-adherent underwrap combined with self-adherent tape.[1,11] The use of self-adherent tape results in a waterproof support since there is no adhesive, and the underwrap also possesses up to 23 times more tensile strength than its foam counterpart.[11] This taping technique may be a better technique since it is proposed to not loosen as much during exercise. Finally, ankle braces are also used to provide prophylactic support to the ankle joint.[12] This is achieved by a lace-up sleeve combined with Velcro-backed straps. Semi-rigid hinge braces are used in some environments to prevent lateral and syndesmotic ankle sprains but are not used as frequently as lace-up braces. [13,14]

An effective prophylactic ankle support must decrease ankle range of motion in regards to inversion and plantarflexion to be effective at reducing lateral ankle sprain mechanics.[15-17] While non-elastic white cloth tape has been shown to reduce the rate of inversion, it has also been found to loosen significantly following exercise.[11] This loosening renders the technique mute since the ankle is now able to achieve almost its full range of motion again. Ankle braces have been found to be effective at reducing the range of motion even following rigorous exercise.[1,13] Self-adherent tape has also been shown to retain more than 50% of its restrictive properties for inversion to eversion, and 65% of its plantarflexion to dorsiflexion restriction abilities following exercise.[11]

While this study will be examining the ability for taping and bracing to reduce range of motion, the latency of peroneal activation following mechanical perturbation also needs to be considered. It is thought by some that the peroneal muscles can activate with enough force to prevent a lateral ankle sprain. And in several studies, it has been shown that taping and or bracing of the ankle increases the latency of the peroneal reflex.[18,19] In previous taping and bracing studies it has been shown that maximal inversion and inversion velocity both decrease due to the taping and bracing.[10] Since peroneal activation starts at between 57.70 ms and 83.3 ms, and it takes anywhere from 150 ms to 175 ms to achieve maximal inversion while using tape and braces, it can be understood that even though the peroneals are activating, they alone cannot prevent maximal inversion.[10,18,19] Therefore, since there are changes that are noticed with previous taping versus bracing studies, and the peroneals will not be able to generate force that is able to alter ankle range of motion, any and all changes that are observed will be attributed to the taping and bracing conditions, not the peroneal activation.

While literature exists showing the effectiveness of various ankle taping and bracing techniques following exercise on reducing the rate of inversion, and degrees of maximal inversion; most measurement criteria has been limited to either non-weight bearing measurements, or to patient-motivated measures, such as the Y-balance test.[1,11] Additionally, some of the available literature is resultant of measurements taken immediately following application of the tape or brace.[10] In clinical practice, athletes are being taped or braced ten or more minutes prior to exercise, and then exercise for a prolonged period of time. Not only are we replicating inversion via the perturbation walkway, but the prophylactic device is being put in a stressed state due to exercise, which is more reflective of conditions an athlete will experience. Replicating the stressors of exercise better replicate the forces that are experienced during athletic activity and will help to fill in a missing piece in existing literature. These results will be clinically applicable as athletic trainers will be able to make recommendations on prophylactic measures for athletes. Therefore, the purpose of this study was to evaluate changes in maximum inversion, time to maximal inversion, and velocity of maximal inversion following exercise in various ankle prophylactic conditions. In addition, patient-perceived comfort while wearing the prophylaxes was assessed.

Methods

Design

We conducted a crossover study with one independent variable (prophylactic condition) with four levels (white cloth tape, self-adherent tape, lace-up ankle brace, and control) and 4 dependent variables (maximum inversion, time to maximum inversion, inversion velocity, and perceived patient comfort).

Participants

In total, 15 participants were included in this study (7 men, 8 women; age = 21.93 ± 1.4 years; height = 171.4 ± 10.2 cm; weight = 70.2 ± 10.9 kg; foot dominance = 3 left, 12 right). Participants were recruited from a large midwestern university population. All individuals who volunteered for this study were physically active and between the ages of 18 and 25. Physically active was defined as someone who exercises at a moderate to high intensity, which equates to 55-85 percent of their maximum heart rate, for at least 150 minutes per week, as per guidelines set forth by the American College of Sports Medicine.[20] Participants who may not have access to a heart rate monitor while exercising were informed that moderate to high intensity was being defined as being able to hold a simple conversation while exercising.[20] Additionally, participants reported no history of injury to the lower extremity within the past two years. This included sprains, fractures, dislocations, and no history of surgeries to the hip, knee, ankle, or foot. Minor injuries such as abrasions and cuts that did not compromise the underlying tissue were ignored. Individuals were excluded if they reported any allergy to the adhesive material. Individuals were excluded if they had any neurological or balance issues. It was required that individuals had at least 30 degrees of passive inversion of the ankle joint, and this was measured via a handheld goniometer. This was done to ensure that each participant had enough range of motion to properly walk on the walkway without injuring themselves. The dominant ankle was used for all testing procedures. Dominance was determined by asking the individual which foot they would use to kick a ball. The study was approved by the Institutional Review Board for the Protection of Human Subjects at Indiana University, and all participants provided written informed consent.

Procedures

Participants completed 4 days of testing (avg: 5.51 days ± 4.16 days between each visit), one for each condition. The conditions were: 1) white cloth tape (Zonas, Johnson & Johnson Consumer Products, Bridgewater, New Jersey) with prewrap (Johnson & Johnson), 2) self-adherent tape (PowerTape, Andover Healthcare Inc, Salisbury, Massachusetts) with self-adherent prewrap (PowerFlex, Andover), 3) lace-up ankle brace (EVO Quatro Ankle Stabilizer, Medical Specialties Inc., Charlotte, NC), and 4) the control with no tape or brace. Both the white cloth tape and the self-adherent tapes were 1.5 inches wide. The order of the conditions was randomized and counterbalanced for all participants. To mimic real-world conditions, ankle taping was done under the participants' socks, while the ankle brace was applied over their socks.

Taping conditions

For the white cloth tape and self-adherent tape conditions, the limb was clean, dry, and was not shaved by the researcher, but may have been shaved prior to data collection prior to participant by themselves, without instruction by the researchers. Heel and lace pads with a small amount of skin lubricant were placed over the Achilles tendon and anterior talocrural ankle joint.

For the white cloth tape conditions, an adhesive spray (Cramer Tuf-Skin, Cramer Products Inc, Gardner, Kansas) was applied over the foot and lower leg, allowing it to dry for approximately 10 seconds. For the white cloth tape condition, foam prewrap was applied starting at the midfoot and continuously wrapped in a circular pattern up to the musculotendinous junction of the gastrocnemius and the Achilles tendon. Starting at the base of the calf, three anchor strips were then applied, overlapping by half of the width of the tape, and a separate anchor strip was applied around the midfoot, just proximal to the base of the 5th metatarsal. Three stirrups were then be applied from medial to lateral, interwoven with circular strips from the base of the anchors to the malleolus. Two heel locks were then applied (one medially and one laterally), a figure-of-8 strip, and finally closing strips were applied (Figure 1).

For the self-adherent tape condition, self-adherent prewrap was applied from the musculotendinous junction of the Achilles tendon and the gastrocnemius-soleus complex in a continuous circular pattern to the midfoot, incorporating a medial and lateral heel lock around the ankle joint. The self-adherent tape was then applied in a similar manner to the white cloth tape method; however, it was manually compressed by the clinician to the subject's ankle following taping to ensure joint conformity as per the manufacturer's recommendations (Figure 2).

All taping procedures were completed by the same clinician. The taping methods were selected as to best reflect current clinical practice techniques.[9] For both taping conditions, the participants were instructed to keep their ankle in full dorsiflexion, and the tape jobs were not redone or removed after initial application.

Bracing condition

The ankle brace, (EVO Quatro Ankle Stabilizer, Medical Specialties Inc., Charlotte, NC) was sized based on the participants reported shoe size according to the manufacturer's guidelines. The boot was laced-up as a shoe would be, followed by the stirrups being brought across the subtalar joint, then underneath the calcaneus and fastened via hook-and-loop tape to either the medial or lateral side. The closing wrap was then completed. The ankle brace was then applied by each participant to themselves while under direct clinician supervision and instruction (Figure 3). Each participant was asked if the device felt tight, and if they did, the clinician tried to put a finger between the boot and the lateral and medial straps. If they were able to, the brace was deemed too loose and the participant was instructed to tighten the lateral and medial straps. Participants were not permitted to re-lace or re-tighten their brace throughout the testing procedures.

Control condition

For the control condition, the participant had no prophylaxis applied to their foot and ankle (Figure 4). They wore their normal socks and shoes for the exercise protocol and wore the controlled shoe for the walkway trials.

Exercise Protocol

The exercise protocol was designed to include dynamic movements to best stress the prophylactic conditions and mimic sport-specific exercises with cutting, jumping, and running. The protocol started with a 5-minute warm-up of the subject's choosing. If participants felt the need to stretch, they were instructed to do so as part of their 5-minute warm-up. The exercise protocol included: agility ladder drills, 4-line run, 4-cone drill, lateral shuffles, and line jumps (Figure 5). Each station was completed in the following manner: agility ladder drills- completion of all 3 techniques once, lateral shuffles- down and back 5 times, 4-cone drill- around the entire square 5 times, 4-line runs- down and back to each line once, and line jumps- for 30 seconds as fast as possible, then a 5 second rest, and then for 30 more seconds as fast as possible. Upon completion of a repetition at each station, each participant then moved to the subsequent station, and a 1-minute water break was given after 8 minutes of exercise. Each subject completed as many circuits of the five exercises as possible, and the number of circuits was recorded. Subjects were asked to exercise for 15 total minutes, in addition to the 5-minute warm up of their choosing. During cutting and change-of-direction movements, subjects were instructed to make turns as sharp as possible, and to cut as sharply as they could when stopping. This was done to stress the prophylaxes as much as possible. During the 4-line-run drill, participants were instructed to not slow down until as late as possible to maximize the cutting force, and therefore the stress placed on the prophylaxes. Participants were instructed to exercise at a moderate to high intensity. Intensity was determined via a heart rate monitor worn by the participant. Heart rate zones were based on age, with moderate intensity falling around 120 bpm on average, and high intensity falling around 160 bpm on average. If the participant's heart rate was too low, or too high, the clinician administering the exercise protocol gave feedback to either slow down the exercises or speed up.

Ankle Mechanics Assessment

Participants walked along a custom-built perturbation walkway in all four conditions following an exercise protocol (Figure 6). The walkway was a 7.2-meter-long custom-built walkway. It included four 1.2-meter-long active sections with a set of doors on the right and left that each open to a 30º angle. An industrial-strength electromagnet held each door closed. A computer randomly selected which door to trigger, and was randomized between the right and left side, and which of the four doors on each side is also randomized. This was to prevent a feed-forward mechanism which would allow each participant to anticipate the door drop. When triggered by a control panel, the voltage supplied to one of the electromagnets decreased to a set point at which it only supported the weight of the door. The moment that a force greater than the weight of the door is applied, the door fell open.

Prior to trials taking place, subjects put on a pair of shoes that was controlled across all subjects (Excelsior training shoe; Adidas AG, Herzogenaurach, Germany), and then a wireless twin axis electrogoniometer (SG110/A, Biometrics, Ltd, UK) was affixed to the lateral ankle joint to measure maximum inversion. Once the electrogoniometer was fixed to the subject's ankle, trials were conducted. Participants were instructed to look straight ahead while walking, and to continue walking normally following the activation of a trap door. When a door dropped, participants were instructed to "ride the door down," and not try to correct their ankle to try to prevent the inversion from occurring. Trials were then conducted, with 5 trials being completed on the side with the prophylaxes applied, or in the case of the control trial, the dominant limb. Doors were randomly activated, and additional trials were added with no doors dropping or it dropped on the non-dominant side so that the participant would not try to anticipate that perturbation. If a door dropped on the non-dominant side, the data was ignored. Participants were not be told which side, or which door would drop. During each trial, the following variables were captured: maximum inversion, time to maximum inversion, and velocity of inversion, which are described below.

Comfort was measured using the Visual Analog Scale found on the *Prophylaxis Comfort Rating* (Figure 7). This was taken once for each of the prophylactic conditions following the walkway testing that day. Subjects were not be able to see how they rated the previous conditions.

<u>Data Processing</u>

Data were captured with Acqknowledge software (version 4.1; Biopac Systems, Inc, Goleta, CA), then imported into a custom MatLAB program (version R2019b; MathWorks, Natick, MA) to calculate maximum inversion, time to maximum inversion, and velocity of inversion. Data was collected at 2000 frames-per-second and filtered using a 4th order, zero-lag, low pass, Butterworth digital filter with an 8 Hz cutoff frequency.

Maximum inversion was measured from the time the door opens and ankle starts to invert on the walkway to when it stops. This was taken a total of 5 times and averaged for each of the prophylactic conditions after the exercise protocol. Maximum inversion was measured in degrees (^{o}).

Time to maximum inversion was measured from the time the door opens and ankle starts to invert to when the ankle reaches max inversion. This was taken a total of 5 times and averaged for each of the prophylactic conditions after exercise. Time to maximum inversion was measured in milliseconds (ms).

Velocity of maximum inversion was measured from the time the door opens and ankle starts to invert to when the door stops. This was taken a total of 5 times and averaged for each of the prophylactic conditions after the exercise protocol. Inversion velocity was measured in degrees per second (^{o}/s).

Statistical Analysis

Descriptive statistics and Hedge's g effect sizes were calculated for the dependent variables across conditions. A Repeated Measures Analysis of Variance was calculated in SPSS (IBM SPSS Statistics 26, Armonk, NY) for each dependent variable with the within subject's factor maximum inversion, time, velocity, and comfort (post exercise) and condition (white cloth tape: WT, self-adherent tape: PT, lace-up ankle brace: B, and control: C). Tukey post hoc test was calculated on any significant differences. A priori alpha level was $\alpha<0.05$. Hedges g effect size was calculated using the following formula: (Mean 1-Mean 2)/Pooled STDEV.

Results

Table 1 contains descriptive statistics for all dependent variables by condition. Table 2 contains Hedge's g effect sizes for the comparisons across prophylactic conditions for each dependent variable. There was a significant difference in ROM between the prophylactic devices, $F_{(3,42)}=6.769$, $p=0.001$, $\eta^2=0.668$, $1-\beta=0.950$. Follow-up analysis indicated that the brace condition reduced range of motion more than the control condition when examining maximum inversion ROM, with a mean difference of 3.6°±0.1° (p=0.001) and a large effect size (g=1.3). There were no statistically significant differences between any other conditions when calculating pairwise comparisons (p>0.05). Interestingly, there was a medium effect size when comparing the brace to both the PowerTape and white tape conditions (g= 0.7) and (g= 0.7), respectively even though these comparisons were not statistically significant.

There was a statistically significant effect for prophylactic conditions for time to max inversion, $F_{(3,42)}=4.079$, $p=0.012$, $\eta^2=0.470$, $1-\beta=0.634$. Follow-up analysis indicated there were no statistically significant differences between the prophylactic conditions when using the pairwise comparisons; however, large effect sizes were noted between several conditions. Large effect sizes were calculated when comparing the brace to the control condition (g= 3.0), the PowerTape condition (g= 2.8), and the white tape condition (g= 0.9). A large effect size was also noted between the white tape condition and the control condition (g= 2.0), as well as the PowerTape condition (g= 1.8).

There was a statistically significant effect for prophylactic condition for the dependent variable velocity, $F_{(2.122,29.714)}=14.706$, $p<0.001$, $\eta^2=0.942$, $1-\beta=1.00$. Sphericity was violated so the Greenhouse-Geisser correction was used. Follow-up analysis indicated statistically significant differences between the brace and control condition (mean difference= 55.6±0.2 °/s, p= 0.01), as well as between the brace and the PowerTape condition (mean difference= 44.3±2 °/s, p= 0.01). As noted in the table 2, a large effect size was found between all four conditions when compared with one another.

There was no statistically significant effect for prophylaxes for comfort rating, $F_{(1.378,19.294)}=2.467$, $p=0.125$, $\eta^2=0.250$, $1-\beta=0.363$. Sphericity was violated so a Greenhouse-Geisser correction was used. However, when examining the Hedges g for effect sizes, a large effect size was found when comparing the brace comfort rating to both the PowerTape condition (g= 2.1), and the white tape condition (g= 2.2), indicating that the brace condition was more comfortable.

Heart rate data was not gathered during data collection, however during the exercise protocol it was routinely monitored by the clinician to ensure that the heart rate was above the participant's minimum and below their maximum heart rate.

Discussion

Overall, our findings suggest a difference between the brace and control conditions, where the braced condition restricted maximum range of motion and reduced the rate of inversion. Since there were only statistical differences with maximum range of motion and velocity of inversion, and not time, this may suggest that the ankle traveled a shorter distance in the same period of time during the brace condition. This is clinically important since it may give additional time for the peroneals to generate a greater contraction to slow the ankle and possibly reduce an inversion ankle sprain. This theory may explain how the body may be able to naturally protect itself from injurious range of motion. The material of the brace also minimizes the distance and speed of inversion, which would help to reduce any excessive tensile loading subjected to the collagen fibers of the lateral ligaments. A previous study found that the brace condition lowers maximum inversion, results in greater time to maximum inversion, and thus equates to a lower inversion velocity.[10] The current study provides further support that the brace condition may provide a sooner endpoint due to the decreased range of motion, and possibly reduce the likelihood of a lateral ankle sprain.

Incorporating exercise

The novelty of this study was the inclusion of an exercise protocol, and since previous studies had no exercise component, it is challenging to generalize previous findings to the real-world athletic setting.[10] The exercise protocol that we incorporated was chosen as to best reflect sport-specific movements, to simulate what a prophylactic device will be subjected to during athletic participation. While real-world practice times and competitions may reflect a longer exercise period, time constraints regarding data collection required a shorter exercise duration to be used. Since athletic activities usually requiring cutting movements, lateral movements, and short bursts of running, this exercise protocol was chosen. Participants were able to complete approximately the same number of circuits regardless of the presence of the brace, both taping techniques, and the control condition. While Purcell et al[11] showed that over 30 minutes of moderate intensity exercise, self-adherent tape proves to be more restrictive than white cloth tape, this study did not agree with those findings. The aforementioned study examined restrictiveness using an electrogoniometer, but took measurements with the participant seated, and non-weight bearing.[11] Since this study used a dynamic perturbation walkway, as compared to seated, non-weight bearing electrogoniometric measurements, we may have a better understanding as to how restrictive, or not, taping may be. Previous literature states that there is a weakening of protective taping techniques during the course of an exercise program or athletic practice.[21,22] While this study supports some of the previous findings, prior studies did not use a dynamic walkway platform to measure ankle range-of-motion, so these data captured may not be biomechanically accurate during weight-bearing movements. However, there is no conclusive evidence regarding the minimum amount of time it takes for ankle taping and bracing techniques to deteriorate during exercise. Willeford et al[1] found that self-adherent tape and a lace-up ankle brace provided equal range of motion restriction before and after a football practice via a Y-balance test. Zweirs et al[23] added that while taping and bracing techniques were shown to lose their restrictive capabilities during exercise, an athlete's performance is not hindered. However, the loosening of techniques may lead to increased injury risk. In response to this point, an advantage that lace-up ankle braces have is that they can easily be tightened during an athletic competition, taking less time than re-taping an ankle. This also allows the clinician to focus on more urgent scenarios and competition supervision, as opposed to spending an average time of 67 seconds applying ankle tape.[24]

Perceived comfort

Comfort was quantified for each prophylactic device to better understand how a patient tolerates a device. This was deemed important by the researchers since if an individual finds a device uncomfortable, then they will not want to wear it. While no comparisons were statistically significant for comfort, it was found that there was a large effect ($g= 2.1$) comparing the brace rating to the self-adherent tape condition, and a large effect size ($g=2.2$) when comparing the brace to the white tape condition. This indicates that the lace-up brace condition possibly was perceived as more comfortable by the participants. This is important since a majority of collegiate athletic trainers encourage or require taping of their athletes.[9] Since the lace-up brace performed the best in regards to time to maximum inversion and rate of maximum inversion, as well as the comfort rating due the large Hedges g effect sizes, it may be the superior prophylaxis when compared to the self-adherent tape condition and white cloth tape condition.

Mechanical properties of prophylaxis

The differences between both taping conditions and the bracing condition must be examined and understanding them may help to explain the finding of decreased range of motion in the brace condition when using the Hedges g effect size. When comparing white cloth tape and self-adherent tape, there are mechanical differences that result in their ability, or lack thereof to offer inversion restriction. White tape has shown to lose up to 99% of its effectiveness at preventing inversion to eversion, compared to self-adherent tape which has been found to retain up to 50% after 30 minutes of exercise.[11] It has been found that moisture can degrade white tape, thus reducing its effectiveness. Self-adherent tape does not have this issue, since self-adherent underwrap and tape is waterproof and will degrade less and stretch less over time.[11] Purcell et al[11] noted differences in tape restriction after 30 minutes of exercise at a moderate level. When examining effect size for time (g = 1.8) and rate of inversion (g = 1.4), there was a large effect size when comparing the two tapes. Since the self-adherent tape had a greater time to maximum inversion, and therefore, a greater velocity than the white cloth tape, it can be said that self-adherent tape with a self-adherent underwrap may possess less restrictive capabilities regarding maximum inversion than that of white tape with a foam underwrap. Purcell et al[11] did not agree with this finding, instead stating that self-adherent tape provided more restriction following 30 minutes of moderate-intensity exercise. Since these measurements were done seated with an electrogoniometer as opposed to weight-bearing, the results may not be truly accurate to a sports-specific injury mechanism. Even though there was no statistical difference noted in our study between the brace and taping conditions, there may be a clinical difference between the two conditions due to a large Hedges g effect size.

When comparing the mechanical properties of a brace with that of white tape or self-adherent tape, the brace has shown to be superior when examining its ability to reduce maximum inversion as well as reducing rate of inversion. Tensile strength of the bracing material may be a reason as to why it is more restrictive and is used to determine at what tension a material will fail. This is measured in pound-force per square inch or in pounds. With a tensile strength of 430,000 psi, the brace produces more tensile strength than both the white tape which has a tensile strength of 97,474 psi,[25,26] and self-adherent tape with self-adherent underwrap provides a tensile strength of 60 lbs. While pounds-per-square inch and pounds of tensile strength cannot be compared due to limits regarding conversion, it is worth noting that the ballistic nylon in braces possesses a higher tensile strength than both tapes. Previous studies have also shown that a self-adherent underwrap alone possesses up to 23 lbs. of tensile strength, compared to foam underwrap which possesses no tensile strength.[11] The higher tensile strength of the ballistic nylon allows the brace to withstand higher loads and forces than the white tape and self-adherent tape. As is true with self-adherent tape, the ballistic nylon used in lace-up ankle braces is waterproof, which prevents any stretching or degradation due to perspiration or water. Since the brace will likely not degrade as much as tape, this results in a greater ability to restrict ankle movement. When examining restrictiveness, there was a strong effect size for time and velocity when comparing the brace to both taping conditions (table 2). Hall et al[10] found statistically significant evidence that the lace-up ankle brace was more restrictive in regards to maximum inversion, time to inversion, and rate of inversion. While in our study there was only a statistical difference when comparing velocity for the brace and PowerTape (table 1), the large effect size when comparing the brace to both taping conditions during time to maximum inversion and rate of maximum inversion indicates that there could be a clinical difference between the brace and two tape conditions across two of the three measured variables. Even though ankle braces may restrict lateral ankle sprain mechanics better than taping, some clinicians may prefer not use ankle braces due to their higher initial cost when compared to taping.

Cost benefits of bracing versus taping

When comparing bracing to taping, the monetary value, as well as the time commitment of the individual administering the device must be considered as well. When examining the cost of taping 143 basketball athletes prophylactically, it would cost over $15,000 for the season, as compared to just over $5,000 when using a brace.[27] Time commitment must also be examined, when it was found that it takes, on average, 67 seconds for a trained clinician to tape an ankle.[24] This compares to fitting an ankle brace for a patient which will take a few minutes to size them and then show them how to self-apply it, but then takes no additional time for the clinician beyond the initial commitment. While the cost of time and materials does not equal an improvement in protection from lateral ankle sprains, from a budgetary perspective, organizations that may have decreased funds will have to pick an economical solution. Bracing will have a higher up-front cost but may be more economically friendly in the long run. The lace-up brace also performed better than both taping conditions due to the large Hedges g effect size across two of the three variables (time to maximum inversion and velocity of inversion) during our study, so applying a brace versus applying tape may not sacrifice, and could help, restrictive capabilities. An increase in restrictive capabilities can possibly lead to a decrease in the prevalence of lateral ankle sprains. The financial burden of taping paired with its ineffective protection against inversion ankle sprain mechanisms makes prophylactic bracing a reasonable solution for clinicians looking to spend more time providing other care.

Peroneal latency effects

Due to the inversion mechanism of lateral ankle sprains,[15] peroneal activation plays an antagonistic role regarding ankle inversion. The peroneal muscle group is primarily responsible for plantarflexion and eversion, in which the eversion movement counteracts the inversion mechanism of a lateral ankle sprain. In previous studies, it found that the latency time for peroneal activation was anywhere from 57.7 ms to 83.3 ms.[18,19] While our study found that the ankle reached its maximum inversion in 152.5 ms for the brace condition, which was longer than both tape conditions and the control, there may still not be enough time for the peroneals to generate enough of a force to counteract the inversion mechanism by developing enough tension in the muscle and changing the degrees of ankle range of motion.[18,19] However, using a lace-up ankle brace can slow down the rate of inversion and allow more time for the peroneals to react over a set distance. While we may not have found a statistically significant difference for time, it may be a clinically significant finding due to the large effect size between all prophylactic conditions and the control condition. The lace-up brace produced the largest effect size when compared to the control condition (g = 3.0), and to the PowerTape condition (g = 2.8). Since the formula for velocity is v=d/t, the greater the rate of inversion, the less time there is for the peroneals to generate a reactionary response and counteract the inversion mechanism.[18,19] There was also a statistically significant difference between the lace-up brace condition and the control condition in regard to velocity of inversion, showing that the lace-up brace significantly slowed the ankle down during its inversion mechanism. When looking at range of motion graphs, an "M" shaped curve was noted during some trials, possibly showing evidence of a peroneal latency reaction occurring, forcing a small eversion moment. Reactions cannot be controlled by an individual, as it is an involuntary movement. Neuromuscular training has also been shown to decrease the time of the peroneal latency reflex,[28,29] which when paired with an ankle prophylaxis, may have a better effect on reducing the lateral ankle sprain mechanism. Since EMG data was not collected in this study, these conclusions are based on conjecture and not primary data collection.

Clinical significance

Our study found that the ankle brace was statistically better than the control condition at reducing inversion range of motion as well as velocity of inversion. Additionally, the lace-up brace and white cloth tape conditions both had slower inversion velocities compared to the control and self-adherent tape conditions. There was also no statistical difference between the lace-up ankle brace and white cloth tape conditions for any of the dependent variables. This may suggest that lace-up ankle braces and white cloth taping techniques are both effective at minimizing injurious inversion mechanisms. However, despite the lack of statistical significance when comparing the lace-up brace to both taping conditions, we believe the effect sizes calculated from our data provide a strong argument for clinicians to utilize lace-up braces instead of white cloth tape and self-adherent tape. Effect sizes were calculated using Hedges g, with the associated formula: [(Mean 1 – Mean 2)/Pooled STDEV]. An effect size is a quantitative reflection of the magnitude of a phenomenon that is used for the purpose of addressing a question of interest.[30] An effect size of larger than 0.8 indicates that the mean of the group with that variable is in the 79th percentile of the group it is compared to.[31] This is defined as a "large effect size," and while not statistically significant, reflects the magnitude of the difference between two conditions. Since it was observed that there were several effect sizes that were greater than 0.8 in our study, we are able to make the conclusion that due to the large Hedges g effect size across two of the three dependent variables: time to maximum inversion and velocity of inversion, the lace-up brace may have performed better than both taping conditions. Based on the large effect sizes when comparing the brace to the control condition across all three dependent variables, as well as when comparing the brace to both taping conditions across time to maximum inversion and velocity of maximum inversion, the lace-up ankle brace may have a large magnitude of effect on ankle inversion mechanics. Due to this finding of lace-up ankle braces having a large Hedges g effect size when compared to the taping conditions across 2 of the 3 quantitative dependent variables, it may shift the clinician's focus to using bracing techniques compared to the use of taping methods to reduce lateral ankle sprain mechanics.

Limitations

Like most investigations, our study had several limitations. First is the placement of the electrogoniometer. We used anatomical landmarks for placement of the electrogoniometer, which were the distal lead being placed on the velcro of the shoe, the coil bisecting the lateral malleolus, and the proximal lead in line with the shaft of the fibula and in line with the fibular head. Even though these landmarks were used and closely followed, and the same person placed the goniometer on each participant for each trial, it is possible that for some trials the placement was not correct which may have altered data output. Since our placement of the goniometer had to be done on top of the prophylactic devices, as well as anchoring it to the control shoe, we may not have been capturing true ankle inversion since it was not on the skin. The movement of the shoe may have been getting captured as well. Additionally, measurements were not captured on a multi-planar walkway. The perturbation walkway we used only created strict inversion with no plantarflexion. It is not known how adding plantarflexion to the walkway would have altered the ability of the various prophylactic devices to restrict lateral ankle sprain mechanics. It should also be noted that we did not allow participants to re-tighten the lace-up brace following the exercise protocol. This may not reflect a real-world situation if athletes are able to take a break and re-tighten their brace if they feel it loosening. When comparing our primary data to previous studies, the magnitude of our results differed. This is possibly due to involuntary biomechanical compensation occurring at the hip and the knee to try and keep the body safely upright during an inversion moment. Further research should be conducted to examine the biomechanical changes that occur at the hip and knee during ankle inversion to determine what happens further up the kinetic chain, such as possible tibial external or internal rotation, which could be why we saw lower magnitudes in the measured data.

Conclusion

Due to lateral ankle sprains being the most reported injury diagnosis among US college athletes,[1] it should be determined if there are any methods that can be used to reduce this statistic. It is important to examine these methods following exercise, since ankle injuries do not take place immediately after application of prophylactic devices. While all prophylactic techniques resulted in differences when compared to the control condition, not all findings were statistically significant. Across the three measured variables pertaining to ankle inversion, range of motion, time, and rate of inversion, the lace-up ankle brace proved to have the greatest reduction in possibly decreasing injurious frontal plane motion. The lace-up brace condition was also perceived to be slightly more comfortable than both taping conditions when examining the Hedges g effect sizes. When comparing our findings to previous studies, it did not appear that exercise has a significant effect on the restrictiveness of the prophylactic devices, due to similar results when comparing bracing to taping. The data described in this study should help clinicians determine what prophylactic techniques are best for their patients from a mechanical perspective.

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Tables

Table 1: *Descriptive Statistics for all Dependent Variable by Prophylactic Condition (Mean ± STDEV)*

	Maximum Inversion (°)	Time to Maximum Inversion (ms)	Velocity (°/s)	Comfort Rating	Circuits
Brace	14.2 ± 0.7	152.5 ± 10.6	93.3 ± 7.3	7.3 ± 0.5	3.5 ± 0.1
Control	17.8 ± 0.7*	125.9 ± 5.7	148.9 ± 7.1*		3.5 ± 0.1
PowerTape	16.4 ± 0.8	126.7 ± 6.7	137.6 ± 9.3*	6.2 ± 0.4	3.5 ± 0.1
White Tape	16.4 ± 0.9	143.1 ± 10.3	124.5 ± 8.8	6.1 ± 0.6	3.4 ± 0.1

** Indicates a significant difference from the Brace condition ($p<0.05$)*

Table 2: *Hedges g Effect Size for the Dependent Variables Across Prophylactic Condition*

Conditions	ROM			Time			Velocity		
	Brace	Control	Power Tape	Brace	Control	Power Tape	Brace	Control	Power Tape
Control	1.3			3.0			7.5		
Power Tape	0.7	0.5		2.8	0.6		5.2	1.3	
White Tape	0.7	0.4	0.01	0.9	2.0	1.8	3.7	2.9	1.4

Legend to Figures

Figures

Figure 1: White cloth taping sequence; A- foam underwrap with heel and lace pads, B- anchor strips, C- stirrups and circular strips, D- heel locks, E- figure-of-8 strip, F- closing strips and finished taping

Figure 2: Self-adherent taping sequence; A- self-adherent underwrap with heel and lace pads, B- anchor strips, C- stirrups and circular strips, D- heel locks, E- figure-of-8 strip, F- closing strips and finished taping


Figure 3: Ankle braces; lace-up brace

Figure 4: Control Condition

Figure 5: Exercise Protocol

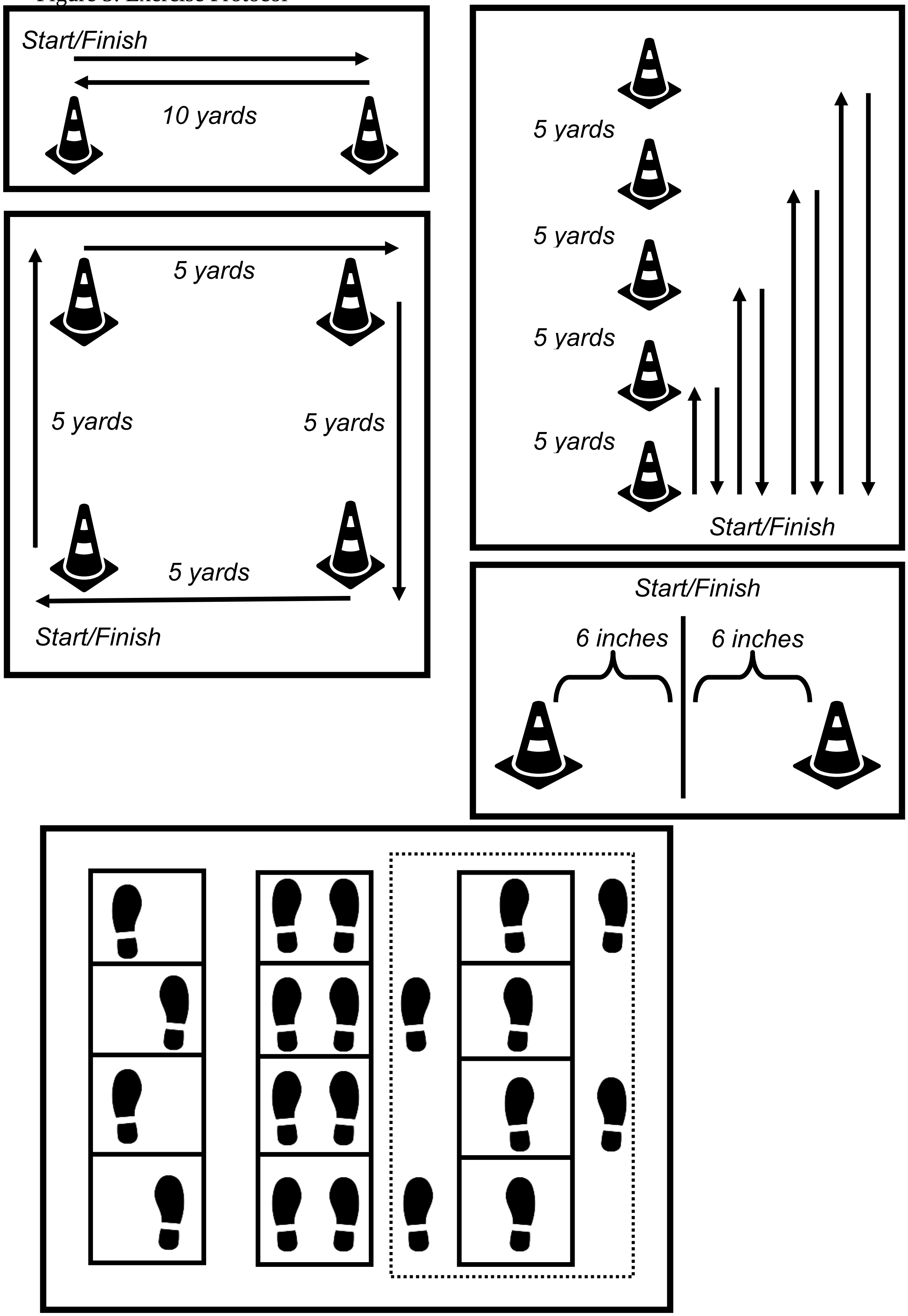

Figure 6: Perturbation walkway

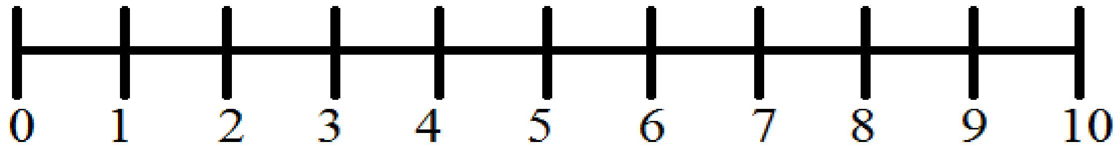

Figure 7: VAS scale for participant-perceived comfort rating.

SAMUEL L. COGEN, MS, LAT, ATC, CES

Education

Indiana University- *Bloomington, IN* **May 29th, 2020**
- Master of Science in Kinesiology
- Emphasis in Athletic Training
- CAATE-Accredited Post-Professional Athletic Training Program
- Thesis: Examining the effectiveness of ankle prophylaxes on reducing lateral ankle sprain mechanics following exercise.
- 44 credit-hours
  - Upper and lower extremity evaluation
  - Spinal examination
  - Neurotrauma
  - Advanced rehabilitation
  - General medical conditions and pharmacology

Ohio University- *Athens, OH* **May 5, 2018**
- Bachelor of Science in Athletic Training
- CAATE-Accredited Professional Athletic Training Program

Sycamore High School- *Cincinnati, OH* **June 6, 2013**
- College Preparatory Degree

Professional Experience

Indiana University- *Bloomington, IN* **2019-2020**
- Athletic trainer.
  - Men's Tennis- 2019-2020
    - Traveled to all away spring matches as the sole athletic trainer.
    - Conducted rehabilitation and return-to-play exercises for two post-surgical patients.
  - Coed and All Girls Cheerleading 2019-2020
  - Assisted in conducting orthopedic screening during mass pre-participation examinations.
  - Baseball- 2019
    - Assisted the staff athletic trainer with coverage of over 30 athletes.
    - Traveled to away games with team.
    - Preceptor to two undergraduate students.
    - Covered baseball camps hosted by the team's coaching staff.
  - 2019 Women's Swim and Dive B1G Ten Championships

Bloomington Blades Ice Hockey- *Bloomington, IN* **2019**
- Covered games for a local high school hockey team.

Indiana University Club Ice Hockey- *Bloomington, IN* **2019**
- Covered games for the Indiana University DII hockey team.

Owen Valley Middle School- *Spencer, IN* **2019**
- Athletic trainer.
- Covered boys' and girls' basketball, wrestling, and track and field.

Bloomington High School South- *Bloomington, IN* **2018**

- Athletic trainer.
- Preceptor to two undergraduate students.
- Assigned to football, boys' and girls' soccer, boys' basketball, and wrestling.
- Traveled solo to away JV/Freshmen football games and all away soccer games.

JCC Maccabi Sports Camp- *Atherton, CA* **2018**

- Certified athletic trainer for 300 athletes ages 8-15.
- Performed injury evaluations, emergency care, and prophylactic techniques for campers and staff.

Professional Credentials

Indiana Professional Licensing Agency **2018-present**

- Licensed Athletic Trainer
- 36003027A

Board of Certification (BOC) **2018-present**

- 2000032332

National Provider Identifier (NPI) **2016-present**

- 1003274523

Graston Technique (GT) **2018-present**

- M1 Credentialed Provider

Corrective Exercise Specialist (CES) **2019-present**

- National Academy of Sports Medicine
- 1190372640

American Red Cross **Expires August 2020**

- Certificate ID: GWK4HI
- CPR/AED for Professional Rescuers
- Responding to Emergencies First Aid

Undergraduate Clinical Experience

Alexander High School- *Albany, OH* **2018**

- Senior student at rural high school. Was the primary responder for JV games and assisted with educating sophomore and junior students.

Wilkes-Barre/Scranton Penguins- *Wilkes-Barre, PA* **2017**

- Athletic training internship.
- Professional minor league hockey team affiliated with the Pittsburgh Penguins.

Ohio University Division II Club Hockey- *Athens, OH* **2017, 2018**

- Assisted with providing athletic training services to Division 2 Club Hockey games during weekend tournament and regular season games.

Athens Marathon Medical Team- *Athens, OH* **2017**

- Assisted in medical coverage at a mile marker and then at the finish line during the 50th Annual Athens City Marathon.

Meigs High School- *Pomeroy, OH* **2017**

- Assigned to rural high school. Assisted in immediate coverage of M/W basketball, track, softball, and baseball.

Ohio University Football- *Athens, OH* **2016**

- Worked with and traveled with Ohio University's Division I FBS football team.

Ohio University Club Sports- *Athens, OH* **2016**

- Assisted in coverage of all 30 club organizations available on campus.

Ohio University Performing Arts Clinic- *Athens, OH* **2015**

- Worked with members of The School of Dance, Theatre, Music, and Marching Band.

Teaching Experience

Indiana University **2019**

- Teaching Assistant for senior-level K488: Advanced Topics in Athletic Training class
- Covered goniometry, manual muscle testing, PNF techniques, joint mobilizations, and ambulatory techniques

Bloomington High School South **2019**

- Guest lecturer for high school sports medicine class.
- Presented on emergency care techniques in athletic training, as well as knee anatomy and evaluation techniques

Ohio University **2016-2017**

- Teaching Assistant for gross anatomy labs and hosted open labs for sophomore class.

Leadership Experience

Ohio Athletic Trainers' Association **2016-2018**

- Student Senate Southeast Representative and Public Relations Chair/Webmaster.
  - Served 2016-2018.
  - Responsible for updating OATA Student Senate Facebook page and Website.
  - Remained in contact with ATEP Program Directors in the Southeast District to keep them updated on developments within the Student Senate.
- Attended OATA Student Symposium in 2016, 2017, and 2018.
- Attended OATA General Meeting in 2016, 2017, and 2018.

Ohio University Student Athletic Training Organization **2015-2017**

- Vice President from 2016-2017
  - Responsible for communicating with President and Program Director to develop Organization Events.
- Class Representative from 2015-2016
  - Responsible for communicating with classmates regarding upcoming events and volunteer opportunities

Awards and Presentations

Poster Presentation at Ohio Athletic Trainers' Association State Meeting **2018**

- Symptomatic L4-L5 Disc Herniation in a Professional Hockey Player.
- Published in Journal of Sports Medicine and Allied Health Sciences; Volume 4, Issue 1, Article 11. DOI: *10.25035/jsmahs.04.01.11*

Outstanding Graduating Athletic Training Student **2018**

- Ohio University Athletic Training Class of 2018.

Professional Organizations

National Athletic Trainers' Association **2015-present**

Great Lakes Athletic Trainers' Association **2015-present**

Indiana Athletic Trainers' Association **2018-present**

National Strength and Conditioning Association **2020-present**
National Academy of Sports Medicine **2019-present**
Ohio Athletic Trainers' Association **2015-2018**

Continuing Education

National Athletic Trainers Association

- 70th Clinical Symposia and AT Expo, June 24-27, 2019
  - Las Vegas, NV

Great Lakes Athletic Trainers' Association

- 48th, 49th, and 50th Annual Meeting and Symposium
  - March 13-17, 2018
  - March 8-11, 2017
  - March 9-12, 2016
    - Chicago, IL

Ohio Athletic Trainers' Association

- General Meeting in May 2018
  - Columbus, OH
- Student Symposium in January 2018
  - Columbus, OH; Hosted by The Ohio State University
- General Meeting in May 2017
  - Sandusky, OH
- Student Symposium in January 2017
  - Toledo, OH; Hosted by Toledo University
- General Meeting in May 2016
  - Columbus, OH
- Student Symposium in January 2016
  - Athens, OH; Hosted by Ohio University

Additional Work Experience

Ohio University, *Athens, OH* **2016-2017**

- **Tutor**
  - Tutor for introductory and mid-level athletic training courses.
  - Worked with students a minimum of 25 hours each semester.

Goldman Union Camp Institute, *Zionsville, IN* **2014-2017, 2019**

- **Senior Programmer/Assistant Pool Director/Head Songleader**
  - Planned and directed opening day and closing day procedures
  - Planned, directed, and set up each session's Color War
  - Planned a camp-wide carnival
  - Responsible for daily pool operations.
    - Conducted water testing twice-a-day and daily equipment safety checks to ensure camper safety.
    - Oversaw and directed pool maintenance crews and the lifeguard team composed of 7 lifeguards.
  - Responsible for all music operations on camp.
    - Managed music staff of eight individuals.
    - Planned and led song sessions for campers ages 7 to 15.

Ohio University Intramural Sports, *Athens, OH* **2013-2015**

- **Referee**
  - Refereed small-side and full-field intramural soccer matches.
  - Technical Instructor for soccer referees in 2014 and 2015.

United States Soccer Federation, *Cincinnati, OH* **2009-2017**

- **Grade 7 Referee**
  - Refereed U13 to U19 matches. Officiated adult amateur matches as Grade 7 Referee.
  - Awarded 4th-official assignment for semifinals at 2016 Region 2 Youth Championships out of 216 referees.